



ORIGINAL ARTICLE

Comparison of osteometric femoral bone dimensions among the South Africans of different ethnic groups and South African whites

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KEYWORDS

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Abstract Objectives: The main objective of this paper was to use femoral data to determine whether the different South African ethnic groups should be considered as a homogenous population, as has been assumed in previous studies. Furthermore regression equations for each ethnic group were constructed.

Methods: Three standard femoral variables were used; bone length (BL), maximum head diameter (HD) and bicondylar width (BCB). The eight South African ethnic groups (Zulu, Tswana, Swazi, Sotho, Xhosa, Shan, Venda and Ndebele) were considered as the independent variable. They were also compared with femora from South Africans of European Descent (SAED). In total 230 male femora were obtained from the Dart's Collection at Wits University, South Africa.

Results: There were not any significant differences in bone length between the eight South African ethnic groups. However, bone length for SAED was significantly longer than for six of the ethnic groups, all except Zulu and Ndebele. Similarly all of the ethnic groups were significantly smaller than SAED for head diameter and bicondylar width. The Zulu and Ndebele femora were significantly larger than the other six African ethnic groups for HD and BCB. Regression equations were derived for the maximum length of femur from the maximum head diameter for all the groups separately.

Conclusion: Femora from SAED were significantly larger than for six of the eight African ethnic groups that were considered. However, the data from the Zulu and Ndebele femora suggest that they constitute a separate ethnic grouping. Thus we conclude that these eight South African ethnic groups cannot be considered as a homogenous population and that the Zulu and Ndebele groups should be considered as a distinct population.

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1. Introduction

Skeletal dimensions remain one of the most important factors in identifying victims in cases of bomb blasts, earthquakes, decomposed bodies, burn victims and in other natural disasters. Since 1882, anthropometry, which is a field of forensic science, has been used to reconstruct the biological profile of the deceased. This includes variables such as age, sex, ethnicity and stature.^{1,2} Estimation of stature is considered as one of the main parameters of personal identification.^{1,2} It is well accepted that skeletal dimensions vary among different geographical regions, populations and ethnicities, and that standards for one population might not be appropriate for another population.^{3,4}

Sex determination from different bones⁵⁻⁷ and stature reconstruction from femur, tibia, talus, calcaneus, metatarsal, skull, mandible, clavicle, radius, ulna, and sternum have all been previously reported.⁸⁻²² Furthermore, stature estimation has also been calculated from hand and feet dimensions.²³⁻²⁷

In 1983, Lundy²⁸ studied the Southern African population on the basis of metrical and non-metrical features of the post-cranium. He found few significant intertribal differences in the morphological variation of postcranial skeleton of South African ethnic groups (Negro), concluding that "there is little justification for maintaining the tribal subdivision". However, it is worth noting that he did not employ multivariate statistics in order to elucidate the interactions between variables.²⁹ Earlier De Villiers studied skull parameters and concluded that South African tribes may be regarded as sample of a single population.³⁰ On the basis of these findings subsequent studies have assumed that these ethnic groups (mostly Zulu, Sotho, Xhosa) were a homogeneous population and the data from the different ethnic groups were combined for statistical analysis.

In a study conducted on variations in the proximal part of the femur of African population by Cutland, the bones belonged to Zulu tribe alone.³¹ Asala³² in a study on sexual dimorphism in South African populations, collected 260 femora from different tribes, and grouped them as a single group constituting South African blacks and compared them with the South African whites (SAED). The literature predominantly combines together the data from Zulu, Sotho and Xhosa tribes.⁴ However there are some studies where intertribal differences have been found, such as Macho, where significant differences were found between Zulu and Sotho tribes.²⁹

Skeletal dimensions are population and sex-specific due to genetic differences, isolation, differences in biological and environmental factors.⁴ Variation in femora has been reported in the past.²⁸ Recent studies confirmed that South African whites (SAED) are osteologically distinguished from the Caucasoid population in Europe and North America.³³⁻³⁶ It is therefore important to develop a database of bony dimensions for different African populations which may be used later to confirm the ethnicity of victims.

The aim of this study was to collect osteometric data on male femora of eight different African ethnic groups and SAED, and to determine whether these ethnic groups should be considered as a homogeneous population. The three dependent variables were femoral bone length, femoral head diameter and femoral bicondylar width. The eight South African ethnic groups and the SAED were considered as the independent variable.

Correlation between the dependent variables was calculated as were regression equations for calculating the maximum femoral length for each ethnic group and for the SAED. The eight South African ethnic groups that are being considered in this study have not previously been compared with each other. This study will therefore provide a useful contribution to the forensic science of stature reconstruction of unknown victims from different ethnic groups in South Africa.

2. Methods

The skeletal remains used in this study were obtained from a large collection of bones at the Raymond A. Dart Collection of Human skeletons housed in the School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa. A total of 230 femora were selected from eight different Africans tribes and from SAED using a simple random sampling technique. Femora with apparent deformities were excluded (epiphyses fully fused). The sample consisted of African ethnic groups included Nguni language speaking Zulu ($n = 25$), Xhosa ($n = 25$), Swazi ($n = 25$), Ndebele ($n = 33$), Setswana speaking Tsuwana ($n = 24$), Sesotho speaking Sotho ($n = 25$), Shan ($n = 25$), and Venda ($n = 24$). Twenty-four femora of SAED were also selected for comparison. Only male femora were used as there were not enough bones in the collection to provide a balanced sample of female bones from different ethnic groups. This Dart collection of human bones was prepared from dissection hall subjects, hence the gender and ethnic origin were documented for each bone.^{37,38} The age ranged from 29 to 65 years, however, age should be regarded as an approximation, because individuals from these populations very seldom know their year of birth with certainty.²⁹

The parameters measured were previously established and recommended by Martin and Saller³⁹ Parameters measured were:

1. *Maximum femoral length (BL)*: the linear distance between the most superior part of the head of femur and the most inferior part of the medial condyle.
2. *Head diameter (HD)*: maximum diameter of the femoral head.
3. *Bicondylar breadth (BCB)*: the linear distance between the medial border of the medial condyle and the lateral border of the lateral condyle.

The maximum length of the femur was measured on an osteometric board accurate to the nearest 1 mm while the rest of the parameters were measured directly on the bone by using a TA electronic digital vernier caliper (Global selective Equipment cc, JHB, South Africa) accurate to 0.01 mm (Figs. 1a-1c). All the measurements were repeated three times to minimize any chance of measurement error. The measurements were reproducible and repeatable with an error of 0.05 mm.

Statistical analysis was done using SPSS. One-way ANOVAs were used to calculate between-group differences. Post hoc Duncan tests were used to find differences between individual ethnic groups. Pearson's correlations were used to determine the relationship between the three dependent variables; HD, BCB and BL. Furthermore, the regression analysis was conducted to estimate the maximum length of the femur from HD for each African ethnic group and SAED group.



Figure 1a Femoral bone length (BL) being measured on an Osteometric board.



Figure 1b Bone condylar breadth (BCB).

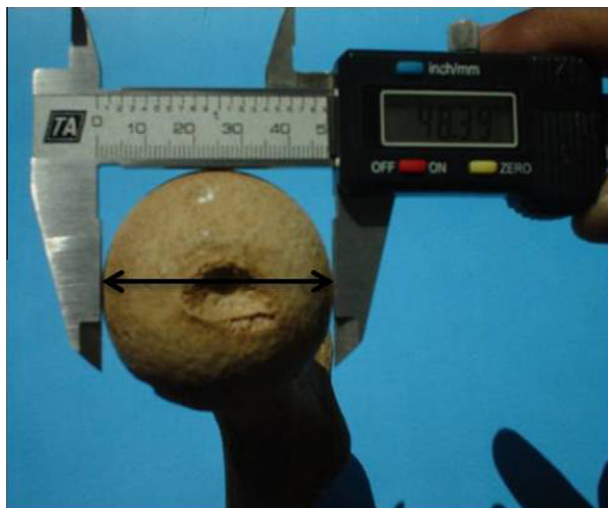


Figure 1c TA Electronic digital caliper measuring maximum head diameter (HD) of the femur.

3. Results

The data for all three dependent variables and for each of the eight ethnic groups and the SAED are shown in Table 1. There are significant between-group differences in the ANOVAs for each of the femoral parameters. In addition the post hoc analysis, shown in Fig. 2, indicates that there are systematic differences between the different ethnic groups. BL of SAED was significantly longer than all the African tribes except Zulu and Ndebele (Fig. 2a).

The post hoc analysis also separated the BCB into three groups (Fig. 2b), with SAED as the largest BCB, followed by Zulu and Ndebele which were significantly larger than all the other tribes ($p < 0.05$), and smaller than SAED ($p < 0.05$). Sotho, Tsuwana, Xhosa, Shan, Venda and Sawazi showed the smallest femoral condyles ($p < 0.05$).

HD dimensions revealed the same pattern (Fig. 2c). SAED was grouped as the largest ($p < 0.05$), Zulu and Ndebele as medium size and the other six ethnic groups as significantly smaller. No significant differences were found between Sotho, Xhosa, Shan, Tsuwana, Sawazi and Venda for any of the dependent variables.

As was expected HD and BCB showed strong correlation with the BL (Table 2).

Regression equations for each tribe were estimated for the femoral maximum length from the head maximum diameter (Table 3), and standard error of estimate was calculated for each South African tribe and SAED. HD was found to be the most reliable parameter from the proximal femur showing strong correlation with the femoral bone length. The overall combined regression equation for the six South African ethnic groups was:

$$\text{Males : } (5.464 \times \text{HD}) + 213.58; \quad \text{correlation} = .632; \\ \text{SEE} = 19.30$$

Regression equations for the individual African tribes are given in Table 3.

The results of this study revealed that SAED femora were significantly larger than the African ethnic groups studied. Zulu and Ndebele ethnic groups revealed larger HD and BCB from the other African ethnic groups studied.

4. Discussion

The main objective of this paper was to use femoral data to determine whether the different South African ethnic groups should be considered as a homogenous population.

Femora from the ethnic groups used in this study have not previously been compared in the literature. The results did not show statistically significant differences in the femoral bone length among the eight African tribes. However, head diameter and condyle width were significantly larger in the Zulu and Ndebele ethnic groups when compared with the other six African tribes.

This study clearly revealed that femora from SAED were the longest and the HD and BCB the biggest, as was expected. The bone length of SAED was significantly longer than for all of the African ethnic groups except for the Zulu and Ndebele. The Zulu and Ndebele tribes' femora were longer than the femora of the other six African tribes. The Tsuwana, Swazi, Xhosa, Sotho, Venda, and Shan did not show any significant

Table 1 Mean, standard deviations and univariate *F*-ratio for femur in MALE.

	SAED/South African Ethnic groups	BL (mm)		HD (mm)		BCB (mm)	
		Mean	SD	Mean	SD	Mean	SD
1	SAED (<i>n</i> = 24)	475.6	25.85	47.53	2.59	77.27	4.05
2	Zulu (<i>n</i> = 25)	462.6	22.67	45.28	2.33	74.33	5.08
3	Ndebele (<i>n</i> = 33)	461.6	26.51	45.67	3.07	73.30	4.71
4	Shan (<i>n</i> = 25)	458.0	26.18	44.58	2.92	70.80	3.38
5	Venda (<i>n</i> = 24)	456.8	29.88	44.75	2.58	72.50	4.10
6	Sotho (<i>n</i> = 25)	455.4	22.63	43.27	2.36	70.58	4.58
7	Xhosa (<i>n</i> = 25)	453.7	22.56	44.34	2.70	65.94	3.76
8	Swazi (<i>n</i> = 25)	450.1	20.03	42.23	2.66	71.51	3.99
9	Tsuwana (<i>n</i> = 24)	447.3	19.24	44.58	2.21	73.06	4.07
	<i>F</i> -ratio	2.318		6.465		4.972	
	<i>p</i> Value	.013		.000		.000	

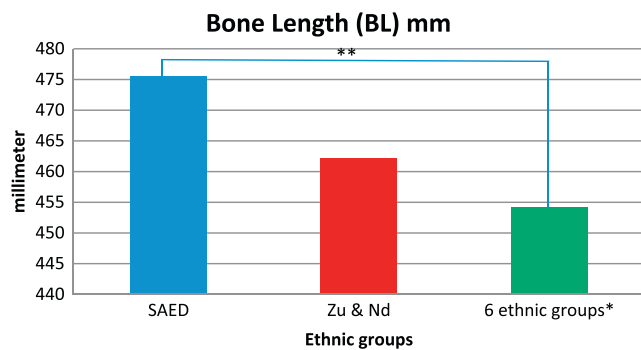


Figure 2a Femoral length showing significant difference between SAED and six tribes, however no significant difference between SAED and Zulu (Zu) and Ndebele (Nd) ethnic groups.

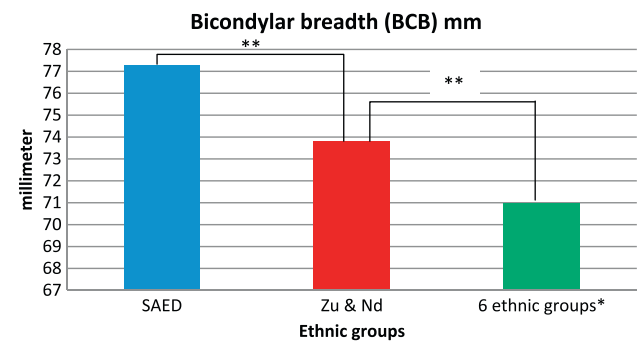


Figure 2b Bicondylar breadth (BCB) measurements showing SAED femoral condyle as the biggest followed by Zulu (Zu) and Ndebele (Nd) and smallest for the rest of the six ethnic groups showing no significant difference among them.

difference among themselves, hence they can be considered as a homogenous population. This is in agreement with Macho's study.³⁷ Lundy also reported that bone length and epicondyle width of the Sotho were the smallest however the maximum head diameters did not show any differences among the tribes.²⁸ Due to this homogeneity among the six tribes in bone length, it is well accepted that these tribes belong to a single group.

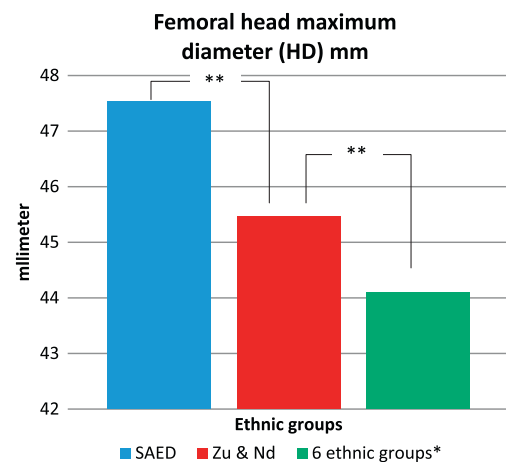


Figure 2c Femoral head were classified into three groups showing SAED femoral head as the biggest followed by Zulu (Zu) and Ndebele (Nd) and smallest for the rest of the six tribes showing no significant difference among them.

Table 2 Correlation of HD and BCB with maximum bone length (BL).

	SAED/South African Ethnic groups	HD		BCB	
		<i>r</i>	<i>p</i> -Value	<i>r</i>	<i>p</i> -Value
1	SAED (<i>n</i> = 24)	.524	.009	.347	.097
2	Zulu (<i>n</i> = 25)	.693	.000	.494	.012
3	Ndebele (<i>n</i> = 33)	.508	.003	.407	.019
4	Shan (<i>n</i> = 25)	.736	.000	.559	.004
5	Venda (<i>n</i> = 24)	.615	.001	.532	.007
6	Sotho (<i>n</i> = 25)	.631	.001	.471	.017
7	Xhosa (<i>n</i> = 25)	.399	.044	.242	.234
8	Swazi (<i>n</i> = 25)	.685	.000	.479	.015
9	Tsuwana (<i>n</i> = 24)	.603	.002	.413	.045

Macho studied Zulu, Sotho, Xhosa tribes^{29,37} and found similarities between Zulu and SAED. This study is in agreement with Macho in the fact that differences in bone length among SAED and Zulu were not significant. Macho in another study mentioned that a morphological gradient seemed apparent between Sothos, Zulus and Xhosas and that

Table 3 Equations for estimation of maximum length of femur (BL) in mm, correlation and standard error of estimate (SEE) from maximum head diameter (HD) of femur in males.

	SAED/South African Ethnic groups	Equation	Correlation	SEE
1	SAED	$(5.231 \times \text{HD}) + 226.941$	.524	22.52
2	Zulu	$(6.745 \times \text{HD}) + 157.153$	.693	16.69
3	Ndebele	$(4.373 \times \text{HD}) + 261.93$	.508	23.20
4	Shan	$(6.594 \times \text{HD}) + 164.001$	.736	18.11
5	Venda	$(7.108 \times \text{HD}) + 138.77$	.615	24.08
6	Sotho	$(6.044 \times \text{HD}) + 193.852$	.631	17.944
7	Xhosa	$(4.173 \times \text{HD}) + 256.545$	.497	20.126
8	Swazi	$(5.143 \times \text{HD}) + 232.891$	.685	14.908
9	Tsuwana	$(5.253 \times \text{HD}) + 213.168$	.603	15.694

differences between South African tribes and Europeans were marked.³⁷ This study strongly supports Macho's assertions.

Lundy²⁸ reported that significant differences were observed between the Sotho and the other Natal Nguni tribes which are in agreement with De Villiers's study.³⁰ However, in a study by Asala,³² 260 bones from African black populations were grouped together due to many similarities among them, although the author mentioned that it was necessary to determine race-specific standards of the parameters.

Regarding the correlation of different parameters, HD and BCB showed a strong correlation with BL in all the groups. Therefore HD values were used to develop the regression equation to calculate the maximum length of the bone. This study is in agreement with Purkait et al.⁷ and Asala³² that HD is the most important variable when determining bone length.

Among the long bones, the femur was chosen because it is the most studied bone, having been used for sexual dimorphism and reconstruction of stature.^{3,7,28,29,31–33,35–44}

Forensic experts and skeletal biologists have a difficult task in identifying the deceased from their skeletal remains, usually the long bones. The South African population is a very diverse community where white-SAED, black-Africans and brown people (of Indian decent) live side by side. It is therefore important to develop other methods which can accurately identify biological origins such as bone DNA analysis. The use of a common regression equation for different populations living in South Africa is accurate enough to identify the stature of the victim from the bone remains. Recent studies by Bidmos et al. grouped different South African tribes into one group, Indigenous South Africans (ISA)⁴⁵, and then compared them with SAED and an equation for stature reconstruction was developed from different variables or fragments of the femur. In another study he developed a regression equation to estimate the length of the femur, in which he grouped all black South Africans as one group.⁴³ In this study we developed a regression equation for the ethnic groups independently and found that individual equations for an individual tribe did improve the accuracy for some of the ethnic tribes. An increase in sample size could further improve the accuracy of these regression equations.

Our results showed similarities between the six ethnic groups studied, hence they may be considered as a homogenous

population for the purposes of stature reconstruction and forensic identification. However, the Zulu and Ndebele ethnic groups revealed longer femora, bigger head diameter and condylar width than the other six tribes.

The shape of the long bones represents a combination of extrinsic as well as intrinsic factors.⁴⁶ Genetic and environmental factors both contribute to these femoral differences.²⁹ There is a clear variation between the genetic contributions to femoral dimensions from the SAED and from the other ethnic groups. Lifestyle and physical activity, both of which affect the shape of the femur, are divergent between the SAED and the other ethnic groups. Jenkins and Steinberg reported that serological analysis of gene frequencies was not able to distinguish any significant inter-tribal differences.⁴⁷ De Villiers found that the similarities were more striking than the differences²⁰ and Rightmire further confirmed the Jenkins study on South African Negro skull.⁴⁸

Among the African ethnic groups, the Zulu and Ndebele groups showed different femora. These differences may be a result of urbanization and improved living conditions of the Zulus and Ndebeles. At the beginning of the 19th century the Zulus were a military power and since then they have been dominant in South Africa. According to Zulu tradition boys from the age of eight formed the first class of warriors, started receiving military weapons and became well-trained warriors by the age of 18, at which point many dedicated their lives to warfare. These cultural traditions are likely to have affected their body build, becoming taller and stronger.

As for the Zulus, the origin of Ndebele ethnic group is also the Nguni tribe. Thus they are known as the 'cousins' of Zulus. It is therefore likely that there is greater genetic concordance between these ethnic groups than between them and the other six groups considered in this study.

The other six ethnic groups have been considered here as homogeneous. This is supported by the many similarities between these ethnic groups, including inter-tribal marriage, urbanization and modernization of lifestyle and improved diet. Together these factors, all of which influence the physical characteristics of the body, corroborate this homogeneity.²⁹ We therefore conclude that Lundy and De Villiers's conclusions are still valid for most of the ethnic groups, including this subset of six ethnic groups. As a result of this tribal inter-mixing of multiple biopsychosocial factors, more similarities have emerged than differences.

Stature estimates based on long bone measurements require a correction factor to compensate for stature decrease in older people.⁴⁹ Galloway⁵⁰ recognizes 45 as the beginning age for age-related stature decrease and puts forward the following equation:

$$\text{Loss} = 0.16(\text{age} - 45) \text{ cm}$$

However, he did not consider sex differences and increasing rate of loss with age. Eugene Giles has estimated amounts in millimeters, that should be subtracted from maximum stature estimates to compensate for the stature due to aging from 46 to 85 and in both sexes.⁴⁹

Limitation of this study was the small sample size. Where possible further studies should be conducted with larger sample sizes. Finally, this approach could be used for other ethnic groups in South Africa and in other parts of the world where there is a great diversity of ethnicity.

5. Conclusion

This study measured three osteometric parameters of the femur in eight South African ethnic groups (Zulu, Ndebele, Xhosa, Swazi, Tsuwana, Sotho, Shan, and Venda). These were compared with each other and with SAED. On the basis of these comparisons it was determined that while there is femoral homogeneity between some of the ethnic groups there is also a distinct subset of ethnic groups. It is therefore our recommendation that the Zulu and Ndebele ethnic groups be considered as a distinct population when conducting forensic reconstruction or identification. We also suggest that this subset of ethnic groups should be considered in further studies to further elucidate the nature of the differences between these and other populations of ethnic groupings in South Africa.

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